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TRANSPORTATION OF IRON ORE, OPEN-CUT MINES, LAKE SUPERIOR DISTRICT

BY

JOHN A. JOHNSON AND FRANK E. CASH

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TRANSPORTATION OF IRON ORE, OPEN-CUT MINES, LAKE SUPERIOR DISTRICT[1]

By John A. Johnson[2] and Frank E. Cash[3]

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INTRODUCTION

During the 6-year period, 1940-45, 481,485,000 gross tons of iron ore was shipped from the Minnesota, Michigan, and Wisconsin mines of the Lake Superior district. Approximately 367,000,000 tons, or 76 percent, of this ore was shipped from open-cut mines. The production of this large tonnage of iron ore from the open-cut mines of the Lake Superior district during the recent war was an outstanding achievement. It is questionable whether this record-breaking tonnage of iron ore, vitally needed for the successful prosecution of the war, could have been produced without the modern equipment and mining methods used in the district.

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The transportation of iron ore from the open-cut mines of the district is the most important phase of the mining cycle. Although some of the mines still use rail haulage advantageously, this method of haulage has been replaced at most mines with motor-truck haulage or a combination of motor-truck and belt-conveyor haulage.

SCOPE

The transportation of iron ore in this report covers (1) power shovels, (2) rail haulage, (3) trucks, (4) belt conveyors, (5) shipping pockets, (6) accident statistics, and (7) safety rules pertaining to open-cut transportation. The purpose of the report is to discuss briefly and disseminate to the mining industry the modern methods, equipment, and safety practices used in transporting iron ore at the open-cut mines of the district.

The 25 open-cut mines covered herein, located in the Marquette, Cuyuna, and Mesabi iron ranges of Michigan and Minnesota, shipped approximately 44,000,000 tons of iron in 1945, which amounted to 72 percent of the open-cut iron ore shipped from the Lake Superior district.

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Republic Steel Corp.
Snyder Mining Co.

POWER SHOVELS

Power shovels are used to remove the ore from the working breasts in all the open-cut mines under discussion. At most of the mines the ore must be drilled and blasted before loading, but at a few mines drilling and blasting are not necessary.

The first steam shovel was introduced in the Minnesota iron-ore ranges in 1893. The old railroad-type steam shovel was standard equipment until about 1920, when self-propelled shovels on caterpillar treads began to come into general use.4/ The first electric power shovel to be used on the Mesabi range was built in 1919 and put into use in 1920. It was a full-revolving, 300-ton type equipped with an 8-cubic-yard dipper for stripping and a 6-cubic-yard dipper for mining iron ore.5/

4/ Gardner, E. D., and Mosier, McHenry, Open-Cut Metal Mining: Bureau of Mines Bull. 433, 1941, pp. 2 and 3.
5/ Skillings' Mining Review, Jan. 11, 1941, p. 1.

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Nearly all the shovels used in the open-cut mines in the district are of the full-revolving type equipped with caterpillar treads, enabling the shovels to cover larger areas and take wider cuts. The use of caterpillar traction on shovels eliminated the need for tracks on which the shovels operated, cut the labor cost by reducing the size of the pit crew, and increased the speed of loading by providing greater mobility.

Table 1 shows the number of power shovels in use at the 25 open-cut mines grouped as to (1) type of motive power, (2) capacity of dipper, and (3) type of haulage away from the shovel. The shovels listed were powered by electric motors, steam engines, or Diesel engines; gasoline-powered shovels were not being used.

TABLE 1. - Number of power shovels and type of haulage

	Capacity of dipper, cubic yards						
	1 - 1-3/4	2 - 2-3/4	3 - 3-1/2	4 - 4-3/4	5	6 - 6-1/2	Totals
Electric shovels							
Truck haulage	1	9	6	20	6	1	43
Railroad-car haulage	-	3	2	12	2	12	31
Total	1	12	8	32	8	13	74
Diesel shovels							
Truck haulage	1	10	1	1	-	-	13
Railroad-car haulage	2	7	-	-	-	-	9
Total	3	17	1	1	-	-	22
Steam shovels							
Truck haulage	-	-	-	-	-	-	-
Railroad-car haulage	-	2	-	-	-	-	2
Total	-	2	-	-	-	-	2
All shovels							
Truck haulage	2	19	7	21	6	1	56
Railroad-car haulage	2	12	2	12	2	12	42
Total	4	31	9	33	8	13	98

Motive Power

Electricity

Of the 98 shovels listed in table 1, 74, or about 75 percent, are electrically operated (figs. 1 and 2). Most of the electrically operated shovels now used at open-cut mines are equipped with the Ward-Leonard system of control. The incoming power to the shovels is 2,300-volt or 4,000-volt alternating current. An alternating-current motor drives individual direct-current generators, each of which supplies 230- to 250-volt direct current for an individual motor for each shovel motion.

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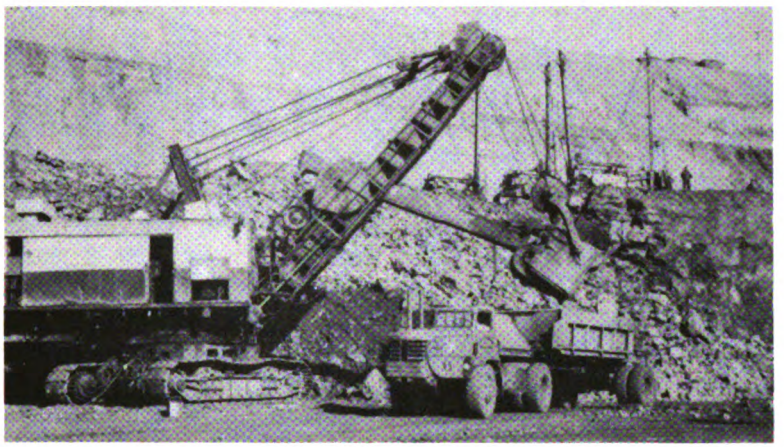

Figure 1. - Electric shovel, 4-yard dipper, loading ore into 35-ton truck trailer wagon.

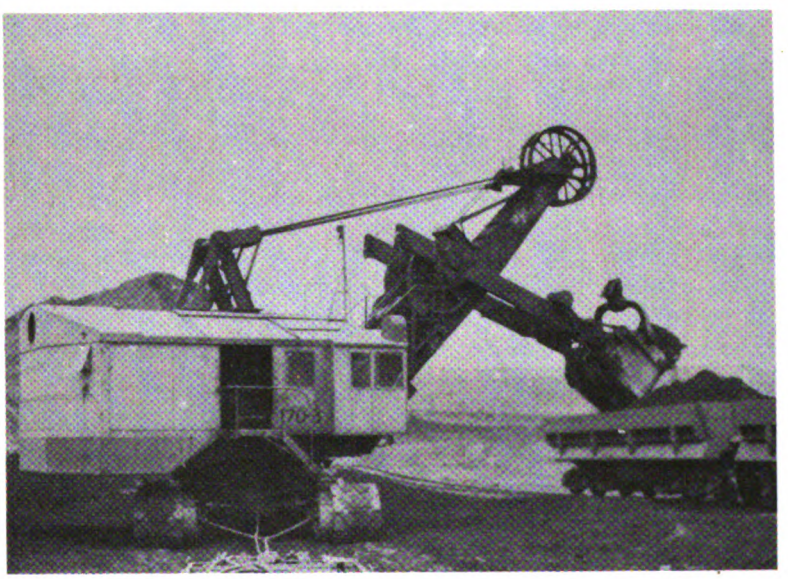

Figure 2. - Electric shovel, 6-1/4-yard dipper, loading ore into 30-yard side-dump cars. Note cable boat behind shovel.

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Generally, power cables are attached to the shovel by a chain or steel cable, which is attached to a clamp around the cable. Cables are coiled on a float or boat (fig. 2) that trails about 30 feet behind the shovel.

The prevention of electric shock to men working about electric shovels deserves primary consideration. Voltage differences between the shovel frame and the ground are the result of an electrical failure within the shovel cable, the power connections, the main motor winding, or the auxiliary power transformers. Such a failure produces a connection between one of the power wires and the shovel itself. The frame of the shovel is then at the same voltage as the power wire. A man who stands on the ground and touches the shovel will receive an electric shock, just as though he stood on the ground and touched the power wire. It is essential that there shall not be a dangerous voltage between the shovel frame and the ground; therefore, it is necessary to have a low-resistance ground connection between the shovel and the earth through which the current may pass.6/

Diesel

Twenty-two, or about 22 percent, of the shovels listed in table 1 are Diesel operated. The Diesel-operated shovels are used generally for small daily tonnages at points where electric power is not available. Table 1 shows that 20 of the 22 Diesel shovels listed have dippers with 1 to 2-3/4-yards capacity.

The cost of operating Diesel-powered shovels compares favorably with that of operating electric shovels. The disadvantages of the Diesel shovels are that the first cost is higher and that more expert attendance is required.7/

Steam

The first steam shovel was introduced into the iron ranges of Minnesota in 1893.8/ Only two of the shovels listed in table 1 were steam-operated, and both of the shovels had 2- to 2-1/2-yard dippers. Prior to 1920, all the power shovels used in open-cut iron-ore mines were steam-operated; these are now becoming obsolete. Some of the disadvantages of steam shovels were (1) the operation and maintenance required a much larger crew than the modern electric- or Diesel-operated shovels; (2) they had to be supplied with coal and water, which required coal handling and maintenance of water lines; and (3) they had to be fired during idle hours to be kept prepared for operation.

6/ Frazee, L. M., Fundamental Principles of Electrical Safety for Open-Pit Iron Mines: National Safety Council, Proc. Lake Superior Mining Section, June 1939, pp. 84-85.

7/ Gardner, E. D., and Mosier, McHenry, work cited in footnote 5, p. 12.

8/ Cash, F. E., and von Bernewitz, M. W., Methods, Costs, and Safety in Stripping and Mining Coal, Copper Ore, Iron Ore, Bauxite and Pebble Phosphate: Bureau of Mines Bull. 298, 1929, p. 3.

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Capacity

The largest shovels in use at the 25 mines had 6-1/2-cubic-yard dippers for loading iron ore. There were 13 shovels of this size, and all were electrically operated. Twelve of these large shovels were used in connection with railroad-car haulage and one was used with truck haulage.

Eighty-one, or 83 percent of the 98 shovels listed in table 1, had 2- to 5-yard dippers. There were 4 shovels with 1- to 1-3/4-yard dippers. Fifty-six of the shovels were loading ore into trucks, and 42 shovels were loading ore into railroad cars.

One company was installing a new electrically operated dragline unit equipped with a 25-cubic-yard bucket for stripping operations.

Dippers

Dippers are constructed of (1) light-alloy steel, (2) manganese steel, or (3) light-alloy-steel dipper with a manganese-steel front or lip. The bodies of modern dippers are of welded construction of rolled alloy-steel plate with manganese-steel lips.

Generally, three types of dipper teeth are used: (1) Reversible forged teeth which are inserted into slots in the dipper-lip casting and fastened to the lip, (2) detachable teeth which fit over the edge of and are bolted or riveted to the dipper lip, and (3) two-piece teeth consisting of a base which is permanently riveted to the dipper and a reversible point which is attached to the base by one bolt.

TRANSPORTATION

Transportation of iron ore from the power shovels and out of the open-cut mines to the yards is accomplished by one of the following methods: (1) Trucks and belt conveyors, (2) steam locomotives and cars, (3) trucks, (4) trucks, belt conveyor, and skips in a vertical shaft, and (5) Diesel-electric locomotives and cars. Table 2 shows the number of mines using each of the five methods of ore haulage mentioned.

TABLE 2. - Ore haulage from open-cut mines to yards

Type of haulage	Number of mines
Trucks and belt conveyors	13
Steam locomotives and cars	6
Trucks	4
Trucks, belt conveyor, and skips in a vertical shaft	1
Diesel-electric locomotive and cars	1
	25

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Methods of hauling the iron ore from the yards to the beneficiation plants are not included in table 2. Two of the mines, listed under Trucks and belt conveyors, formerly used electric locomotives to haul the ore out of the mine. These electric locomotives are used at present to haul the ore from the yards to the beneficiation plants.

Undoubtedly, the greatest change in open-cut iron-ore mining in recent years has been in ore haulage. Truck and belt-conveyor haulage is the most common method used, and it has replaced rail haulage in many open-cut mines where the depth of the mine has required track grades too steep for the efficient use of locomotives. Truck haulage and belt-conveyor haulage also made available a considerable tonnage of ore that was tied up in track benches where rail haulage had been used formerly.

Rail Haulage

Although horses were used to some extent to pull cars at open-cut mines on the Mesabi range as late as 1903, the general use of steam locomotives in open-cut mining began a few years before the present century. Small dinkeys with small hand-dump cars and light, narrow-gage track were in common use in the early stripping operations and also to some extent in ore haulage. Although the earliest locomotives used for hauling ore (weighing 45 to 70 tons in 1903) were not so small as the dinkeys used in stripping work, they, too, were gradually replaced by more powerful and more efficiently designed engines. By 1924 a total of about 300 steam locomotives, ranging in size from 60 to 100 tons, were in use in the Lake Superior district. Electric locomotives were not introduced in open-cut mining in the Lake Superior district until 1924.9/

Seven of 25 mines being discussed in this report utilized rail haulage to transport the iron ore out of the mine; 6 mines used steam locomotives; and 1 mine used Diesel-electric locomotives. Table 3 gives data on rail haulage equipment used, including data on electric locomotives used only for surface haulage to beneficiation plants at 2 of the mines.

Steam Locomotives

Although rail haulage is being replaced by trucks or trucks and belt conveyors to transport the ore out of open-cut iron-ore mines, steam locomotives are used for haulage at more mines than both electric and Diesel-electric locomotives. Table 3 shows that 39 steam locomotives, ranging in size from 18 to 224 tons, were being used to haul the ore out of 6 mines and that five 224-ton steam locomotives were being used for surface haulage to the beneficiation plant at 1 mine. A few other mines, not listed in table 3, used steam locomotives for surface haulage.

9/ Yaworski, N., and Kiessling, O. E., Technology, Employment, and Output per Man in Iron Mining: Works Progress Administration National Research Project and United States Department of the Interior, Bureau of Mines, Rept. E-13, June 1940, pp. 101-105.

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TABLE 3. - Data on rail haulage equipment

Mine	Locomotives					Cars		
	Number	Motive power	Horsepower	Weight, tons	Distance hauled, miles	Type	Capacity, tons	Number of cars to train
2	28	Diesel-electric	1,000	125	4.4 to yard	Hopper bottom	50-75	8 50-ton
	1/5	Steam	-	224	5.5 to plant	Side dump	60	5 60-ton
5	4	do.	-	224	2.6 to yard	Hopper bottom	50-75	8 50-ton
6	4	do.	-	224	.7 to yard	do.	50-75	8 50-ton
8	2	do.	-	70	1.5 to yard	do.	50-75	4 50-ton
	5	do.	-	82	1.5 to yard	do.	50-75	4 50-ton
9	9	do.	-	125	2.8 to yard	do.	50-75	6 50-ton
	1	do.	-	224	2.8 to yard	do.	50-75	8 50-ton
11	1	do.	-	60	(Used as switch engine)			
	6	do.	-	96	3.0 to yard	Hopper bottom	50-75	6 50-ton
	3	do.	-	125	do.	do.	50-75	6 50-ton
12	2/5	Electric	1,000	85	1.6 to plant	do.	75	6 75-ton
14	2/4	do.	660	60	1.5 to plant	Side dump	75	5 75-ton
17	4	Steam	-	18	.5 to plant	do.	7	4-6 7-ton

1/ Steam locomotives used only for surface haulage.
2/ Used only for surface haulage to beneficiation plants.

The 70- to 224-ton steam locomotives haul trains of four to eight 50-ton hopper-bottom cars of ore out of the mines over standard-gage tracks with grades of about 3 percent. The 18-ton steam locomotives haul trains of four to six 7-ton side-dump cars over a 36-inch-gage track with a grade of about 3 percent.

Diesel-Electric Locomotives

Within the last few years, Diesel-electric locomotives (fig. 3) have been used successfully in open-cut haulage in the Lake Superior district. Twenty-eight 1,000-horsepower 125-ton Diesel-electric locomotives haul trains of eight 50-ton hopper-bottom cars of ore out of the mine over normal grades of 3 percent and maximum grades of 5 percent.

One of the mining companies recently ordered four 1,500-horsepower Diesel-electric locomotives for use at its open-cut mines.10/

Electric Locomotives

Electric locomotives had been used until recently for hauling iron ore out of two of the mines. At one mine, 1,000-horsepower 85-ton locomotives were used; and 660-horsepower 60-ton locomotives were used at the other mine. The mines became too deep for rail haulage; and a considerable amount of ore was tied up in track benches, requiring new methods of transporting the ore

10/ Skillings' Mining Review, Feb. 22, 1947, p. 2.

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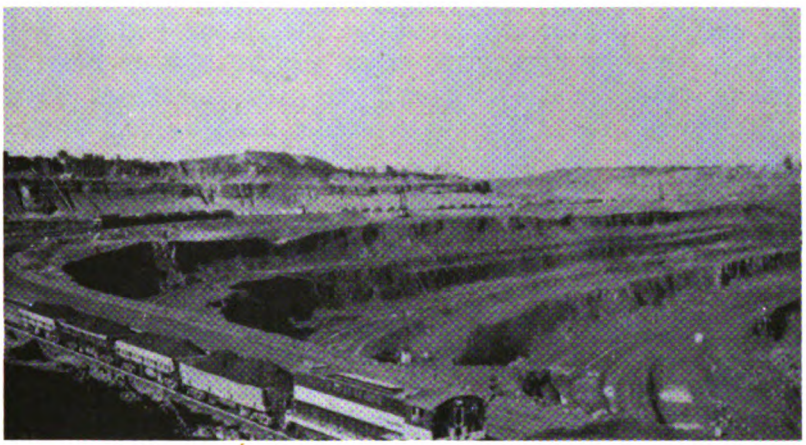

Figure 3. - Diesel-electric locomotives (125-ton, 1,000-horsepower) hauling trains of 30-yard side-dump cars.

Figure 4. - Electric locomotive (85-ton, 1,000-horsepower) hauling train of loaded 75-ton railroad cars.

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out of the mines. Trucks and belt conveyors were installed at both mines, and the electric locomotives are being used to haul the ore from the yards to the beneficiation plants (fig. 4).

Cars

Direct-shipping ore is loaded by power shovels into 50- or 75-ton hopper-bottom railroad cars at six of the open-cut mines visited. At a few mines ore transported to the beneficiation plant is also loaded into 50- or 75-ton hopper-bottom cars, but at some mines ore that is to be beneficiated is loaded into 30-yard side-dump cars (fig. 2). Waste material is hauled in the 30-yard side-dump cars.

Track

All but one of the seven mines using rail haulage are equipped with standard-gage tracks; the one exception is equipped with 36-inch-gage tracks. The mines using heavy rail-haulage equipment usually have tracks laid with 100-pound rails in 33- and 39-foot lengths and 80-pound rails in 33-foot lengths. Untreated 6- by 8-inch hardwood ties, spaced 20 to a rail length, are generally used.

Temporary track sections in 33- or 39-foot lengths, with unstaggered ends, are moved into place by locomotive cranes.

Trucks

Although the first record of the use of trucks to transport iron ore dates back to 1933, the real beginning of heavy trucking, as we know it today, was in 1937. At that time one company started out with three 15-ton trucks, and another company purchased four 20-ton trucks, for open-cut mines in Minnesota. In 1937 truck haulage moved a little over 2 percent of the iron ore shipped from Minnesota open-cut mines. In the 9-year period ended December 31, 1945, the record shows an annual increase in the tonnage of ore moved by truck of 5-1/2 percent, in stripping 7-1/2 percent, and in all material 6-1/2 percent. The figures for 1945 are 32,731,000 tons, or 50 percent, of the total ore shipped, 34,586,000 tons, or 68 percent, of all stripping moved, and 67,317,000 tons, or 58 percent, of the grand total of 116,013,000 tons of all material shipped or moved for the year from all mines and open pits in the area.11/

It can readily be seen from the preceding statistics that truck haulage has been increasing rapidly and has replaced rail haulage in many open-cut iron-ore mines in the district in recent years. Table 2 shows that 18, or 72 percent, of the 25 mines used trucks to haul the ore away from the power shovels; however, the 18 mines using trucks produced only 14,200,000 tons, or 32 percent, of the 44,000,000 tons of iron ore produced in 1945 at the 25

11/ Lindberg, Charles A., Safe Truck Haulage Maintenance: National Safety Council, Proc. Lake Superior Mining Section, June 1946, pp. 33-34.

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mines. One of the mines using rail haulage produced a greater tonnage of iron ore in 1945 than the total tonnage produced by all 18 mines using truck haulage.

Power

Table 4 shows that 241 trucks, including 13 trailer wagons, were used at the 18 mines utilizing truck haulage. Of the 241 truck units listed, 225, or 93 percent, were Diesel-operated; and 16, or 7 percent, were butane-operated. This percentage of Diesel-operated and butane-operated trucks may or may not be representative for the district, as less than one-half of the open-cut mines in the district are included in this report.

TABLE 4. - Trucks and trailer wagons

Type of trucks or wagons	Capacity, in tons					
	35	30	20	15	9	Total
Diesel						
End dump	-	41	51	128	5	225
Butane						
End dump	-	-	3	-	-	3
Side-dump trailer wagons	4	9	-	-	-	13
Total	4	9	3	-	-	16
All types						
End dump	-	41	54	128	5	228
Side-dump trailer wagons	4	9	-	-	-	13
Total	4	50	54	128	5	241

Eighty-one percent of the 241 units listed develop 200 to 275 horsepower, 15 percent develop 100 to 190 horsepower, and 4 percent develop 300 horsepower. The modern heavy-duty trucks used in the mines are equipped with air brakes and with hydraulic hoists for dumping. Most trucks have power-steering mechanism to conserve the energy of the truck drivers. This is installed so that it will not interfere with the regular manual steering if the power steering fails to operate.

Size of Trucks and Tires

The different-type truck-unit bodies used at the 18 mines shown in table 5 are as follows: (1) 228 end-dump trucks ranging in size from 9- to 30-ton capacity, and (2) 13 side-dump trailer wagons (fig. 5) ranging in size from 30- to 35-ton capacity. There were 128 15-ton units, fifty-four 20-ton units, fifty 30-ton units, four 35-ton units, and five 9-ton units used at the 18 mines.

Table 5 shows the size and number of tires used on the different-type truck units. Of the 241 truck units listed, 191 units, or 79 percent, were equipped with a single set of dual-type rear wheels and 6 tires; 45 units, or 19 percent, were equipped with two sets of dual-type rear wheels and 10 tires; and 5 units were equipped with 4 tires. The 10-tire units have capacities of 30 and 35 tons. All of the 20-ton units and the 15-ton units were equipped with 6 tires.

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Figure 5. - Thirty-ton truck trailer wagon.

Figure 6. - Targets with reflecting surface used on road berm.

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TABLE 5. - Size and number of tires on different truck units

Size and number of tires, inches		Number and type of truck units						
		35-ton	30-ton		20-ton	15-ton	9-ton	
Front	Rear	Side-dump trailer	Side-dump trailer	End dump	End dump	End dump	End dump	Total
10-tire units								
(2) 14 x 24	(8) 14 x 24	4	9	-	-	-	-	13
(2) 13 x 24	(8) 14 x 24	-	-	32	-	-	-	32
Total		4	9	32	-	-	-	45
6-tire units								
(2) 14 x 24	(4) 18 x 24	-	-	-	33	18	-	51
(2) 16 x 32	(4) 16 x 32	-	-	9	-	-	-	9
(2) 14 x 24	(4) 16 x 24	-	-	-	16	-	-	16
(2) 14 x 24	(4) 14 x 24	-	-	-	5	-	-	5
(2) 13 x 24	(4) 14 x 24	-	-	-	-	40	-	40
(2) 12 x 24	(4) 14 x 24	-	-	-	-	70	-	70
Total		-	-	9	54	128	-	191
4-tire units								
(2) 10 x 20	(2) 18 x 24	-	-	-	-	-	5	5
Total		-	-	-	-	-	5	5
Grand total		4	9	41	54	128	5	241

The hazards inherent in the inflation of tires have been met in various ways. Special guards are attached to disk-type wheels to prevent the lock rings from flying. Tires are placed in special steel cages while being inflated. There is a simpler technique, which has worked out well at some mines, of inflating the tire while it is lying flat on the floor with the lock ring down and using an inflation chuck which clamps to the tire valve. The air valve and the pressure gage are located on the wall and are controlled at a safe distance from the tire. The locking inflation chuck is also a great time saver over the old hand-held chuck.12/

Roads

The construction and maintenance of good roads are essential to efficient truck haulage. Rough roads or sharp chunks left lying on the roads might cut or bruise one of the pneumatic tires and cause a blow-out. At all except one of the mines visited, the truck-haulage roads were surfaced with lean-ore material. The one exception had asphalt-macadam surfaced roads to within 400 feet of the shovels.

Roads are maintained by using bulldozers, graders, and water sprinklers. At some mines men pick or rake chunks off the road. Roads vary from 25 to 70 feet in width. Most mines maintain roads 40 to 50 feet in width, and one mine reported roads as wide as 70 feet. The embankment side of the roads is usually protected by a berm or windrow of dirt or chunks, with targets

12/ Lindberg, Charles A., Work cited in footnote 11, p. 38.

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(fig. 6), utilizing reflecting material spaced at about 100-foot intervals to warn the truck drivers. At most mines, the truck roads have normal grades of 6 to 8 percent with maximum grades from 10 to 14 percent for short distances.

The distance that ore was hauled by trucks at the mines observed varied from 1/4 to 2 miles, with an average distance of about 1 mile. Waste material was hauled 3/4 to 4 miles, with an average distance of about 1-1/2 miles.

Driving is on the left side of the road at some mines, on the right side of the road at other mines, and a change-over is made from one side of the road to the other between the shovels and the truck dumping stations at other mines. Different mines of the same company follow different driving practices, depending on local conditions. As all the trucks are driven from the left side of the cab, driving on the left side of the road gives the driver better visibility of the side of the road being traveled. Some companies have the cabs offset slightly to the left to give better visibility to the rear on the driver's side. Some officials prefer to have the loaded trucks travel on the highwall side of the road and the empty trucks return to the mine on the embankment side of the road.

Truck Dumping Stations

Fourteen of the mines use trucks to haul the ore to dumping stations at the foot of belt conveyors in the mines; at 13 of these mines the belt conveyors take the ore direct to the surface, while at 1 mine the belt conveyor takes the ore to an underground pocket from where it is hoisted in skips through a vertical shaft to the surface. Four mines use trucks to haul the ore directly to dumping stations on the surface.

At eight of the dumping stations in the mines the trucks back in and end-dump onto grizzlies or directly into pockets. One mine is equipped entirely with side-dump-trailer units, and the units drive directly through the dumping station. At another mine both end-dump trucks and side-dump trailer wagons are used. Drive-over-pocket dumping stations (fig. 7) for end-dump trucks are used in five of the mines.

At all of the dumping stations on the surface the trucks back in and end-dump onto grizzlies at screening plants or directly into railroad cars through an open slide.

As previously stated, five of the mines were equipped with drive-over-pocket truck dumping stations. The floor of the driveway over the pocket opening usually is built in two sections, with rollers underneath that run on steel I-beams. The loaded trucks drive over the pocket and stop when the rear of the truck has cleared the pocket opening. The two floor sections over the pocket are then moved outward by means of air cylinders so that the loaded trucks can dump into the pocket. At one mine operation of the air cylinders is controlled by electric eyes that function when the rear of the truck has cleared the pocket opening. At some mines overhead stop-and-go lights at the pocket let the truck drivers know whether the driveway over the pocket is open or closed.

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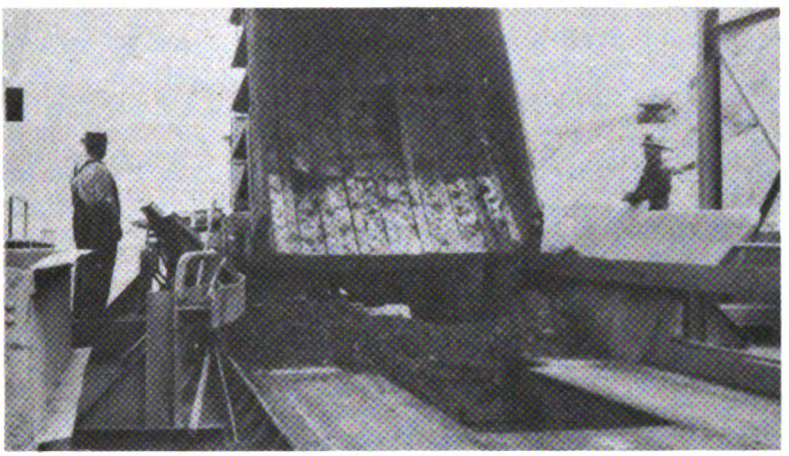

Figure 7. - Drive-over-pocket truck-dumping station.

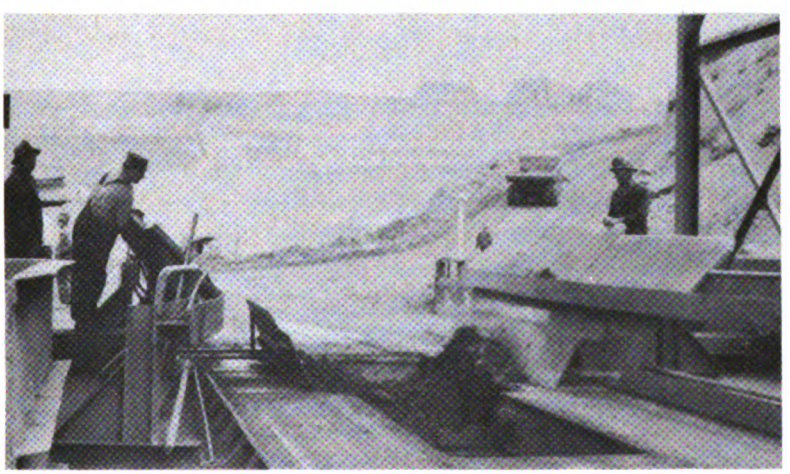

Figure 8. - "Deck swipe" for cleaning spill at truck-dumping station.

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At one mine equipped with a drive-over-pocket, the driveway over the pocket is not movable but has an opening over the pocket through which the ore is dumped. A solid floor is left on each side of the opening for the truck wheels to travel on. Any ore spilled on the solid floor along the sides of the opening is pushed into the pocket by two scrapers (fig. 8) operated by air cylinders.

The drive-over pockets for end-dump trucks save time in dumping, eliminate wear on the trucks, conserve the energy of the truck drivers, and should eliminate accidents caused by backing up loaded trucks.

At several of the mines, the trucks are equipped with an indicator which notifies the truck driver when the truck body is in the normal position. The indicator consists of an L-shaped piece of strap iron attached to the metal canopy over the cab. The metal canopy is fastened to the truck body. The indicator extends down in front of the windshield when the truck body is in the normal position so that the truck driver can see it from his seat in the cab.

Generally, salt solutions are sprayed into the truck or trailer-wagon boxes to prevent material from freezing to the inside of the boxes. At one mine,13/ aprons or "frost plates" made of thin steel sheets, hinged to conform to the floor and front end of the truck box, are used to prevent material from freezing to the inside of the box. These aprons or "frost plates" cover the bottom of the dump box and swing out to hang vertically when the truck is in the dumping position.

Belt Conveyors

The first belt-conveyor system used in iron-ore mining on the Mesabi range was near Nashwauk, Minn., in 1932. This installation involved the movement of wash iron ore mined by underground methods to a washing plant on an adjoining property. The next application of belt conveyors to iron-ore mining in Minnesota was also on the Mesabi range, near Keewatin, in 1936. This was an open-cut operation that had formerly used steam-locomotive haulage, by which means a depth of 225 feet had been attained on a uniform grade of 3 percent.14/ In 1941, Holt15/ reported that 7 out of 32 open-cut iron-ore mines in Minnesota were using belt-conveyor systems to transport the ore out of the mines.

13/ Mahon, Stanley A., Supplementary Remarks on "Safety Practices in Truck Mining": National Safety Council, Proc. Lake Superior Mining Section, June 1942, p. 70.

14/ Anderson, Arthur E., Riddell, J. Murray, and Holt, Grover J., Recent Improvements in Mining Practice on the Mesabi Range: Trans. Am. Inst. Min. and Met. Eng., vol. 141, 1940, pp. 15-16.

15/ Holt, Grover J., Mining and Transportation in Minnesota Iron Mines: Trans. Am. Inst. Min. and Met. Eng., vol. 153, 1943, p. 16.

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A belt conveyor is one of the most efficient means of moving loose materials. As much as 95 percent of the total load is pay load, and only a small percentage of the horsepower is required to run the empty belt. With trucks, the pay load varies from 60 to 70 percent; it is nearly the same for locomotives. A belt conveyor hauling iron ore can operate on maximum grades as steep as 32 percent, thus elevating the material 10 times as rapidly as by steam locomotives and 2 or 3 times as rapidly as by trucks.16/

The use of belt conveyors (figs. 9 and 10) in open-cut iron-ore mining in the Lake Superior district has increased rapidly in the last 6 years, and belts have replaced rail haulage in many of the mines. Table 2 shows that 14 out of 25 mines covered used belt conveyors in the mines. Several other mines had belt conveyors to haul the ore from dumping stations on the surface to beneficiation plants.

Table 6 gives information on the width, number, inclination, length, lift, speed, capacity, and other pertinent details of the belt conveyors used in the 14 mines. The depths of the mines using belt conveyors vary from 100 to 425 feet, with an average depth of 260 feet. The total lifts of the various belt-conveyor systems vary from 40 to 337 feet, with an average lift of 230 feet. At several mines the total lift of the belt conveyors exceeds the depth of the mine because the belts take the ore to the top of railroad-car loading pockets or to beneficiation plants on the surface.

Eight mines used belts 30 inches wide, five mines used belts 36 inches wide, and one mine used a combination of 30- and 36-inch belts. The steepest inclination of any of the belts was 18-1/3° or about 33 percent. One horizontal belt is 1,740 feet long, and one inclined belt is 1,750 feet long (center to center of pulleys).

The capacity of the 30-inch belts ranges from 550 to 1,000 tons of iron ore per hour at speeds of 400 to 550 feet per minute, with an average capacity of about 770 tons per hour at a speed of 500 feet per minute. The capacity of the 36-inch belts ranges from 500 to 1,200 tons per hour at speeds from 300 to 540 feet per minute, with an average capacity of 900 tons per hour at a speed of 450 feet per minute. The ore carried on the belts is usually crushed or screened to a maximum size of 3 to 6 inches before being loaded onto the belts.

Electric motors varying from 30 to 300 horsepower are used to drive the belts, depending upon the speed, inclination, and capacity of the belts. Generally, a 100-horsepower motor is used to raise about 700 tons an hour up a 100-foot lift.

High-tension belt conveyors, with steel-cord construction within the carcass of the belt, have been installed recently in a few of the mines. The first belt of this type used in the open-cut iron-ore mines of Minnesota was installed in 1942.

16/ Yaworski, N., and Kiessling, O. E., Work cited in footnote 9, p. 113.

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Figure 9. - Belt conveyor in open-cut iron-ore mine.

Figure 10. - Belt conveyor from open-cut mine, showing truck approaching dumping station.

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TABLE 6. - Belt conveyors from truck dumping stations in the mines

Mine	Depth of mine, feet	Width of belt, inches	Number of flights	Steepest inclination, degrees	Length of longest belt, feet[1]	Total length of belts, feet[2]	Total lift, feet	Speed of belt, feet per minute	Capacity, tons per hour	Size of ore, inches	Horsepower of motor[3]
3	405	30	1	13-1/2	1,050	1,050	249	500	720	3-1/2	250
7	372	36	5	14	983	2,998	334	500	1,000	3-1/2	150-200
10	260	30	1	13-1/2	1,106	1,106	257	500	750	5-1/2	250
12	400	36	3	18-1/3	627	1,331	293	540	1,200	5-6	200-250
13	275	30	3	18-1/4	324	972	301	400	625	4	100
14	116	36	3	17	260	530	138	450	900	4-1/2	150
15	200	30	1	10	1,750	1,750	262	550	600	4	300
18	100	30	2	12	1,740	3,310	160	500	1,000	5	65-100
19	190	30	3	15	360	980	254	550	1,000	4	100
20	185	30-36	3	15	350	940	231	550	1,000	4	125
21	280	30	3	15	500	1,385	337	550	900	4	125
23	325	36	3	18	340	933	271	435	850	4	75-100
24	120	36	1	18	125	125	40	300	500	3	50
25	425	30	2	11	434	836	86	500	550	5	30-100

1/ Length of longest individual conveyor section.
2/ Total length of conveyor system.
3/ Horsepower of individual motors. Some individual belts are driven by 2 or 3 motors.

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At one mine the belt tension at the drive pulley is about 700 pounds per inch of belt width. With this high working tension, it is now possible to install belt conveyors in one lift, instead of two or three lifts required formerly with fabric belts.

Most of the belt-conveyor systems are equipped with several stop switches along the side of the belts or an emergency stop wire running along the side of the belts and attached to the stop switches. The belts and the pan feeder at the bottom of the conveyor system are synchronized so that if one conveyor stops or is stopped, all units below it will stop. The stop switch or switches must be reset before the conveyor system can be started from the control room.

Generally, the bin at the top of the belt conveyor has an automatic control, consisting of a plate attached to a lever arm, that throws a switch and stops the conveyor when the bin is full. The belt conveyors are equipped with stopping devices to keep the loaded belts from going back when they are stopped. Some have hydraulic brakes which are set automatically when the power goes off and an additional solenoid-operated rachet that engages the main gear wheel.

Some mines have a wooden guard rail (fig. 11) along the sides of the belts to prevent anyone from getting caught in the belt. At most mines the gears and shaft couplings at the drive motors are well-guarded (fig. 12).

Shipping Pockets

The belt conveyors empty into shipping pockets ranging in capacity from 50 to 500 tons, where railroad cars are loaded (fig. 13) for transportation to lake ports or where the ore is loaded into trucks or cars for transportation to beneficiation plants. Most pockets were equipped with air-operated quarter-pan clamshell-type gates, although a few were equipped with hand-operated arc-type gates. Railroad cars were spotted by air brakes (fig. 14) at half of the mines and by hand brakes at half of the mines. The car spotters used safety belts when spotting cars at about half of the mines where hand brakes were used.

Most of the large railroad-car loading pockets were equipped with "spill boards" (fig. 15) which facilitate the loading of the cars to capacity without spilling any of the ore over the sides. Steam locomotives, weighing 540 tons (fig. 16), haul trains of 180 50- to 75-ton cars of ore from the mines to yards near Lake Superior docks.

ACCIDENT STATISTICS

Haulage accidents, which occurred during the 2-year period 1944-45 at the 25 mines, are listed by causes in table 7.

In all, 23,192,398 man-hours were worked at the 25 mines during the 2-year period; and 140 lost-time haulage injuries (including 5 fatalities) occurred, causing the loss of 48,551 man-days. For this period, the haulage frequency rate was 6.04, and the severity rate was 2.09.

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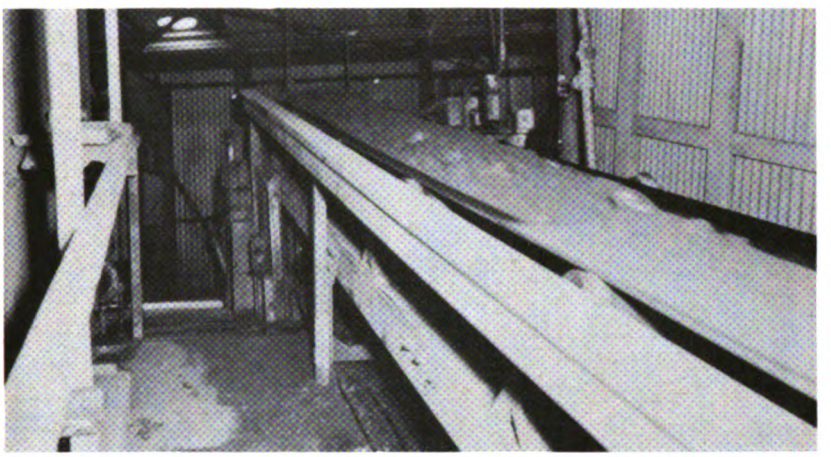

Figure 11. - Belt conveyor, showing wooden guard rail.

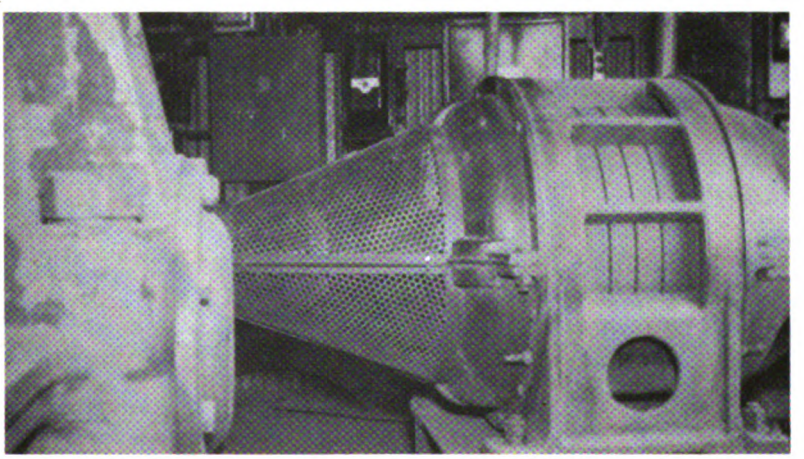

Figure 12. - Guard over coupling and open end of motor-driving belt conveyor.

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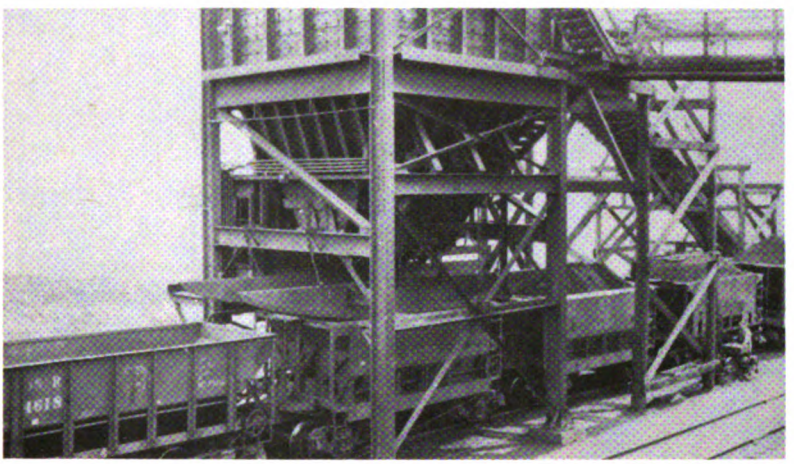

Figure 13. - Loading 50- and 75-ton railroad cars at upper end of belt conveyor.

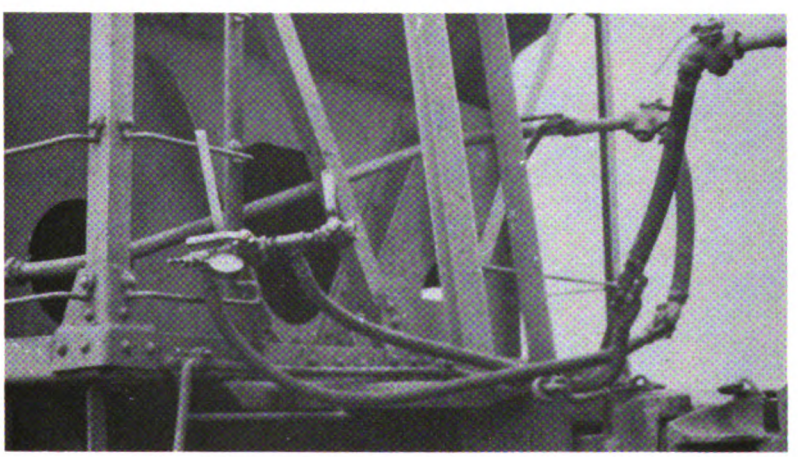

Figure 14. - Air-brake control valves for dropping cars at loading pocket.

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Figure 15. - Loading 75-ton railroad cars at crushing plant, showing spill boards.

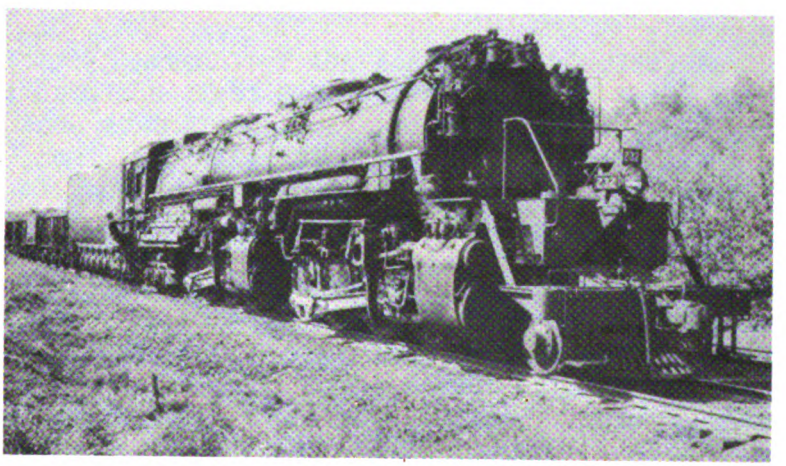

Figure 16. - Steam locomotive, weighing 540 tons. Hauls 180 50- to 75-ton cars of ore from mines to Lake Superior docks.

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TABLE 7. - Haulage injuries (25 open-cut mines) 1944-45

Cause of injury	Number of injuries	Total days lost
Jumped or fell from moving vehicles	1/27	13,264
Repairing shovels, cars, locomotives, and trucks	25	929
Handling rails, ties, and track	15	2,540
Handling railroad cars	13	3,408
Working on or about power shovels	13	2,310
Hurt at steering while driving trucks or tractors	9	153
Truck or tractor tipped or went over bank	2/8	6,392
Dumping cars or trucks	6	3,093
Maintaining truck roads	6	1,413
Collision of trucks, trains, or trucks and trains	5	301
Handling chunks at grizzlies	3	225
Working around belt conveyors	3	145
Falling chunks from chutes, dippers, trucks, and cars	3	124
Hit by moving train	1/2	12,000
Run over by truck	1	2,250
Working on steam locomotives	1	4
	140	48,551
Man-hours worked	23,192,398	
Frequency	6.04	
Severity	2.09	

1/ Includes 2 fatalities.
2/ Includes 1 fatality.

Approximately 73 percent of the lost-time injuries, including two fatalities, occurred from the first six causes listed in table 7, namely: (1) Jumped or fell from moving vehicles, (2) repairing shovels, cars, locomotives and trucks, (3) handling rails, ties and track, (4) handling railroad cars, (5) working on or about power shovels, and (6) hurt at steering wheel while driving trucks or tractors.

In compiling table 7, the available description of some injuries left a doubt as to the exact classification, and the separation of haulage injuries from other types of open-cut injuries was not always well-defined. However, a study of the main causes of injuries listed will reveal the important occupational hazards pertaining to haulage and should help in eliminating similar accidents in the future.

Table 8 is a summary showing the accident experience of all reporting open-cut iron-ore mines and beneficiation plants in the Lake Superior district for each of the 6 years 1940-45, inclusive, and the average for the 6-year period. The table shows an increase in the frequency rate during the last 2 years. It also shows an increase in the severity rate during the first 3 years, a decrease for the next 2 years, and an increase for the last year. The severity rate for 1945 was higher than the 6-year average.

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TABLE 8. - Accident experience at open-cut iron-ore mines and beneficiation plants, Lake Superior district, 1940-45[1]

Year	Number of mines and plants	Man-hours worked	Number of injuries	Days lost	Frequency rate per million man-hours	Severity rate per thousand man-hours
1940	38	8,869,185	61	23,486	6.88	2.65
1941	61	14,007,215	120	51,315	8.56	3.66
1942	79	16,606,290	181	100,119	10.89	6.03
1943	76	20,916,864	310	95,949	14.82	4.59
1944	67	16,770,414	235	34,414	14.01	2.05
1945	67	16,809,051	188	70,568	11.18	4.20
Average	65	15,663,169	182.5	62,642	11.65	4.00

1/ Mahon, S. A., Review of Accidents in the Lake Superior District: National Safety Council, Proc. Lake Superior Mining Section, June 1946, p. 96.

SAFETY RULES

Most of the mining companies in the district have adopted safety rules, from past accident experience, for preventing injuries at their mines and plants. These rules are usually printed in pamphlet form and distributed to all employees. Following are some of the safety rules pertaining to open-cut transportation.

Power Shovels

1. Moving machinery on power shovels shall be properly guarded.

2. Walkways and stands shall be equipped with suitable handrails.

3. Boom ladders must have an approved guardrail.

4. When shovel is in operation, signals shall be given before shovel can be moved.

5. The dipper shall be on the ground with the bail down when men are working on the boom.

6. No one shall crawl under any electric shovel to inspect or oil same without cutting off power by opening switch or cut-outs feeding power to the cable of the shovel.

7. No machinery shall be lubricated or worked upon while in operation with the exception of oiling or greasing the chain or cable.

8. Climbing on or off a revolving shovel while it is in motion is prohibited.

9. To avoid surprise movements of shovel on caterpillar belts while loading, shovel operator shall be responsible for securely blocking shovel.

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10. Pitmen must not work under the boom during digging operations and must remain away from the bank side as much as possible.

11. Men shall not work around or partly under the car being loaded when shovel is in motion.

12. Employees shall keep away from shovels and trucks while loading.

13. Trucks or wagons shall be loaded on shovel operator's side wherever possible.

14. The shovel operator shall see that loads are properly distributed.

15. Shovel operators shall not swing dipper over truck until truck is stopped and driver is in a safe position.

16. The shovel dipper shall not swing over cab of truck.

Locomotives, Trains, and Cars

1. Except when otherwise authorized, only employees whose duties require them to do so shall ride on locomotives or cars.

2. Riding in the gangways of steam locomotives is prohibited.

3. The locomotive engineer shall be responsible for movement of his train and must give proper warning signals when locomotive or train is to be moved and when approaching shovels, curves, washing plants, and track crews.

4. Footboards, side steps, gangways, and running boards on the sides of locomotives must be kept free of foreign objects or materials.

5. Locomotives or trains in motion shall be boarded from the side only.

6. No one shall attempt to get on or off a moving locomotive or train unless he has the use of both hands, and unless the locomotive or train is moving at such a speed that he can get on or off in safety.

7. Employees shall not go between cars, or locomotives and cars, in motion, to adjust air appliances or brakes, to couple or uncouple cars, or for any other purpose.

8. When it is necessary to go between cars, employees shall, as much as possible, avoid stepping on the rails, drawheads, couplings, air hoses, or safety chains.

9. Before a brakeman or other employee goes between cars that are not couples to each other, the cars must be stopped a safe distance apart.

10. Getting on or off dump cars in motion is prohibited. A brakeman intending to ride in an empty dump car (permissible only at certain mines)

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shall take a position in the box of the car before giving the engineer the signal to move, and will remain in the box until the train has been brought to a stop.

11. Employees crossing the track either in front of or behind a standing locomotive or train coupled to a locomotive must cross the track at least 25 feet from the locomotive or train.

12. Walking on tracks is prohibited. Signs prohibiting this practice shall be posted.

13. Locomotive engineers, firemen, and brakemen will have a physical examination once a year.

14. Brakemen must not use their feet to adjust couplers when making a coupling and shall be in full view of the engineer or fireman before the locomotive is moved.

15. Brakemen must stand in the clear when spotting cars at shovels. They shall see that cars are properly loaded and trimmed.

16. Under normal conditions, inability of the engineer or fireman to see either the brakeman or his lantern shall be construed as a stop signal.

17. When there is doubt as to the signal given or for whom it was intended, the engineer shall investigate and remove that doubt before moving his train or proceeding further.

18. A stop signal shall be complied with, regardless of by whom it is given.

19. Between sunset and sunrise, or when vision is restricted by for or other conditions, every locomotive shall display headlights to front and rear.

20. Between sunset and sunrise and at other times when vision is restricted, a red tail light shall be displayed on the head end of every train of dump cars.

21. When setting cars out on grade, the brakeman will place a clamp on the rail to prevent cars from running away.

22. Making flying switches or kicking cars is prohibited.

Dumping and Cleaning Cars

1. When dumping stripping cars on a dump, care should be taken to remove any chunks lodged on top of the car doors that may cause injury to dumpmen or others.

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2. When center-hinged dump cars are being cleaned, they must be blocked securely in the dumping position.

3. When dump cars are being cleaned, pistons must be maintained in dumping position with the air on.

4. When dumping strip cars on a dump, no employee shall stand on the dump side of the train unless his presence there is necessary.

Tracks and Switches

1. Public footpaths and highways crossing tracks at grade shall be properly planked. At such crossings, signs shall be erected to warn traffic coming from either direction.

2. All frogs, switches, and guardrails must be kept properly and securely blocked.

3. Where tracks cross either overhead or underneath other tracks or highways, inside guardrails extending at least two rail lengths on each side of the crossing shall be installed.

4. Whenever practicable, switch stands shall be installed at least 6 feet from the nearest rail and on the side presenting the least hazard to the person operating the switch.

5. Material piled at the side of a track must be at least 6 feet from the nearest rail.

6. When track shifting is done by the locomotive crane, all men must stand clear of the boom.

Trucks

Supervisors

1. A positive blocking device should be provided and secured in locked position when work is being done on unit with box in raised position.

2. Raised ridges, particularly for winter work, shall be provided on the outer bank of all roadways.

3. Main haulage road for two-way traffic should be 40 to 50 feet in width, with easy curves and good visibility.

4. White or reflecting markers shall be used to mark roads for night operation, and appropriate markers used to designate wash-outs, narrow roads, or other dangerous conditions.

5. Icy conditions on roads must be eliminated by use of sand, calcium chloride, or other suitable material.

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6. A dumpman shall be stationed wherever material is to be dumped.

7. A minimum of 24 hours of training shall be required for operators of motorized equipment.

8. All trucks shall be provided with head lamps, tail lamp or lamps, rear red reflectors, windshield wipers, windshield defroster, sun visor, fire extinguisher, first-aid kit, and warning horn or whistle.

9. Power cables should cross roads overhead.

Truck Drivers

1. Getting on or off any piece of motorized equipment while same is in motion is forbidden.

2. Coasting down-grade with the clutch out and the transmission or auxiliary in neutral is forbidden.

3. Passengers are prohibited from riding on trucks, tractors, or any part of motorized unit unless authorized by foreman. Men riding in box must be seated.

4. Driver shall see that box is in down position after dumping.

5. At no time shall a loaded truck approach another from the rear nearer than 50 feet. On down-grade the distance shall be 100 feet.

6. Driver shall not leave his truck with motor running. Motor must be killed and set in gear, with brakes securely set, and truck headed or backed into bank whenever possible.

7. Before backing any truck, driver must give back-up signal (three blasts of horn) and be sure everyone is in clear behind him.

8. Trucks must be at a dead stop when starting motor or shifting gears to start truck.

9. Select a gear which will insure safe driving before ascending or descending steep grades, and do not change gears while going up or down.

Dumping Trucks

1. Dumpman must stand well in clear on driver's side while trucks are backing into dump and while dumping.

2. Markers shall be used to indicate safe dumping limits.

3. Dump boxes must be cleaned in a safe place, out of line of traffic.

4. Long-handled scrapers shall be used for cleaning boxes.

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Conveyor Belts

1. Drive mechanism at the conveyor head shall be well-guarded.

2. The approach of the belt to the head pulley shall be guarded for at least 6 feet to prevent anyone from getting caught between the pulley and the belt.

3. The sides of all tail pulleys shall be guarded.

4. Belt joints shall be vulcanized.

5. Pull cord or cords shall be installed so that the belt or belts can be stopped from any position along the line.

6. Adequate brakes shall be installed on all belt-driving units to prevent belts from running in reverse in case of power failure.

7. Inclined walkways shall be kept free from slipping hazards by installing safety treads.

8. Walkways shall be installed where men must pass over moving belts.

Handling Cars at Loading Pockets

1. When cars are dropped at loading pockets, the main line shall be protected from runaway cars by a derail or stub track installed below the point where loaded cars are usually stopped.

2. Before dropping cars to or from a loading pocket, car riders must make sure that the cars are coupled.

3. No car rider shall attempt to drop more cars than he can safely control, and cars must be under control from the time movement starts.

4. When cars are to be left standing, a sufficient number of hand brakes must be set up to hold the cars.

5. Before operating a car puller, the operator will see that everyone is in the clear, and not in danger of being struck should the cable or hook break or the hook become disengaged.

6. When possible and feasible, the movement of cars at loading pockets shall be controlled by compressed air.

7. When air brakes are to be used, the air-brake system on all cars shall be fully charged immediately before the cars are dropped away from the loading pocket.

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8. To prevent the movement of cars while the air-brake system is being charged, a sufficient number of air brake retainers or hand brakes must be set up before the air brakes are released.

9. When controlling cars by hand brakes, the car rider shall wear an approved car rider's belt, with the hook attached to the car.

10. No brake-stick longer than 28 inches shall be used in operating a brake on a railroad car.

11. Before moving empty cars, brakes shall be inspected, and, whenever possible, the brakemen shall ride on the last car.

12. Cars shall be moved slowly so as not to bump other cars too hard.

13. Men "haying" or plugging holes in cars shall be provided with and use a rope for getting in and out of cars.

SUMMARY

A review of the haulage equipment and methods used in the transportation of iron ore at 25 open-cut mines in the Lake Superior district shows that trucks and belt conveyors have replaced rail haulage in many of the mines during the last decade.

Shovels operated by electricity predominate, although a few Diesel-operated shovels in the smaller sizes are being used, and steam shovels are almost obsolete.

Twenty-eight 1,000-horsepower 125-ton Diesel-electric locomotives are being used at one mine. Four 1,500-horsepower Diesel-electric locomotives have been ordered. Electric locomotives are used at two mines for surface haulage. Steam locomotives are used to haul ore out of six mines.

Diesel-operated and butane-operated trucks, hauling pay loads of 9 to 35 tons out of the mines, are being used at 18 of the 25 mines. These trucks operate on average grades of 6 to 8 percent and maximum grades of 10 to 14 percent.

Belt conveyors are used for open-cut haulage at 14 of the 25 mines. The belts carry 500 to 1,200 tons per hour at speeds ranging from 300 to 550 feet per minute. The longest belt in use was 1,750 feet from center to center of pulleys, and the steepest inclination of any of the belts was 18-1/3° or 33 percent.

The mining companies in the district have well-established safety departments and have adopted and printed safety rules for the prevention of accidents. Some of the safety rules pertaining to open-cut transportation are included in this report.

The accident-frequency rate for open-cut iron-ore mines in the district increased from 1940 to 1943 and decreased during 1944 and 1945, and the rate for 1945 was below the 6-year average. The accident-severity rate also increased from 1940 to 1942 and decreased during 1943 and 1944; however, the rate increased in 1945 and for that year was above the 6-year average.

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